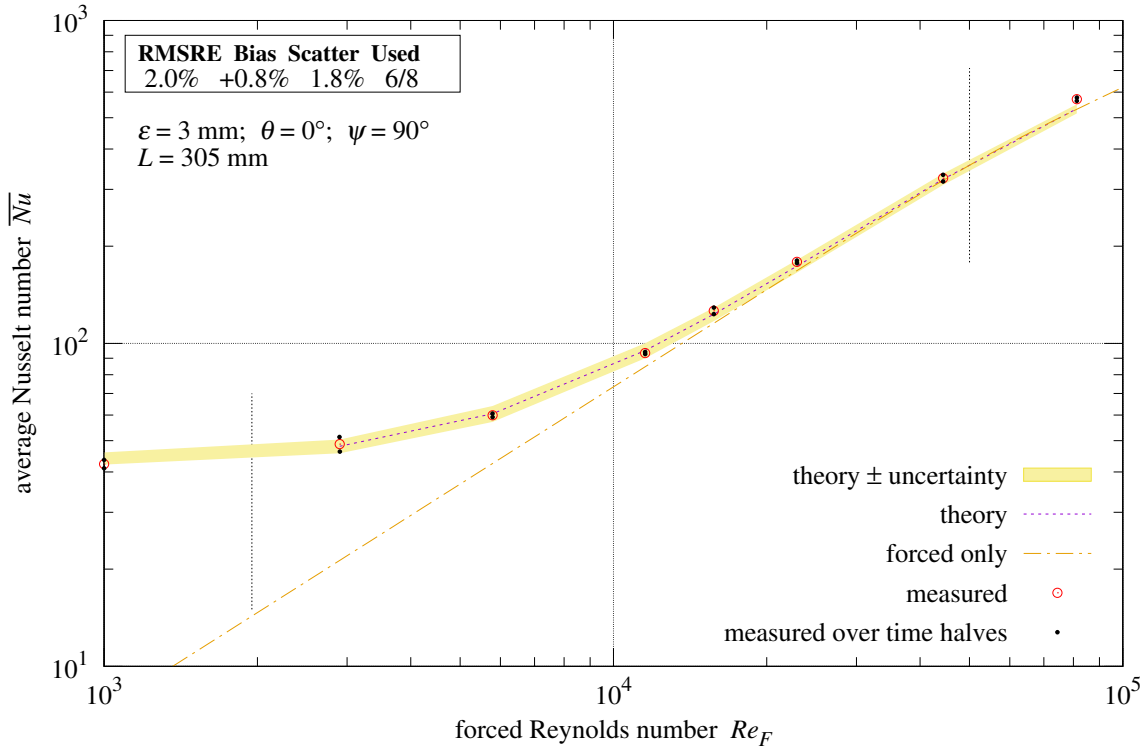
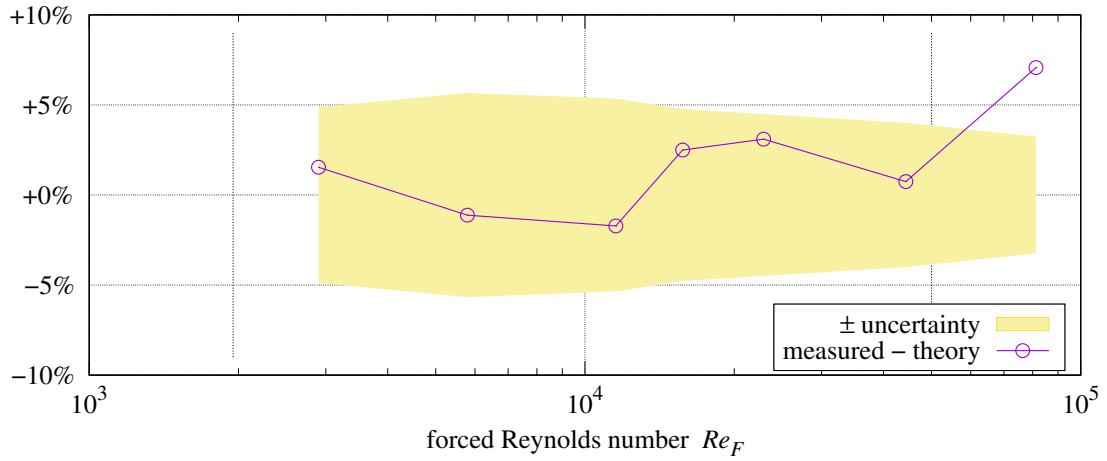


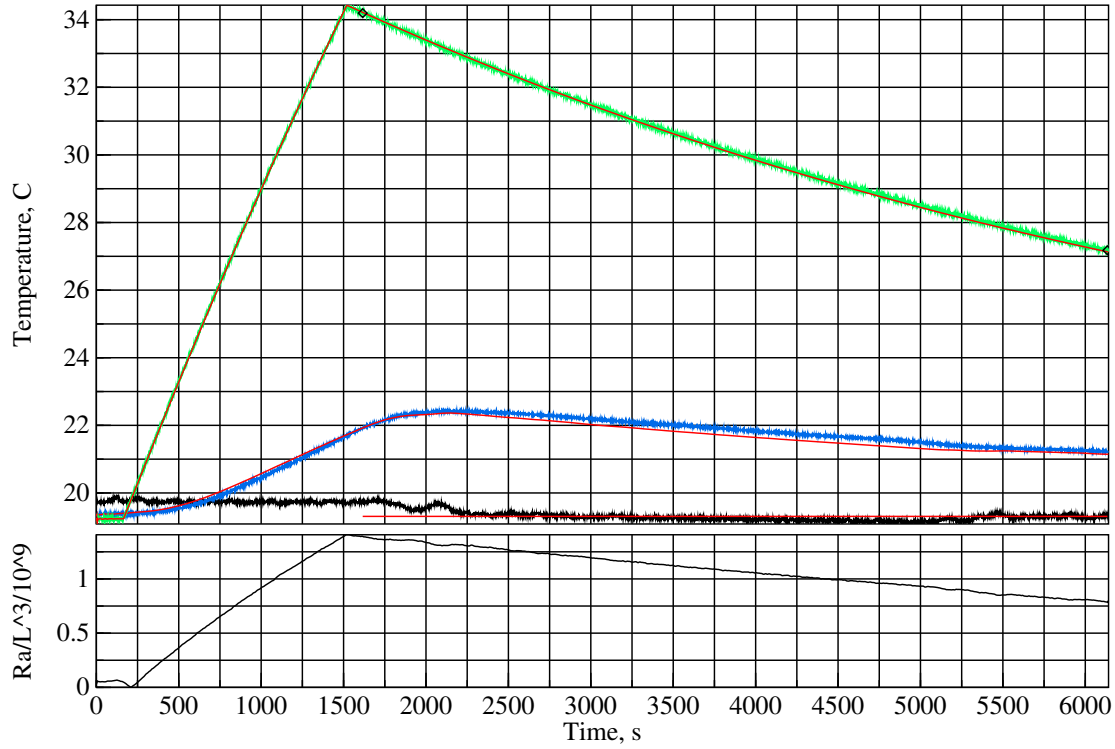
vertical plate, level flow



vertical plate, level flow

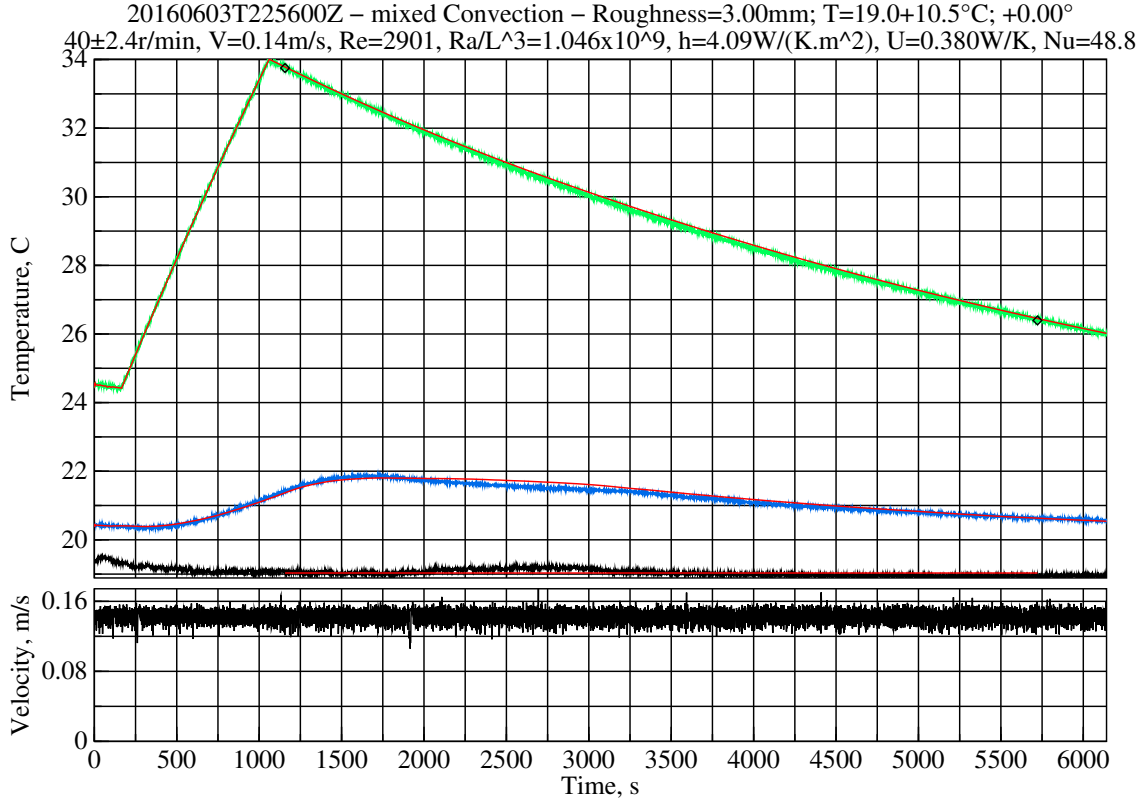


20160603T202311Z – mixed Convection – Roughness=3.00mm; T=19.3+11.0°C; +0.00°  
k=0.0256, Ra/L^3=1.079x10^9, h=3.55W/(K.m^2), U=0.330W/K, Nu=42.3, Pr=0.710



Estimated measurement uncertainties of natural convection at  $\theta = 0.0$ .

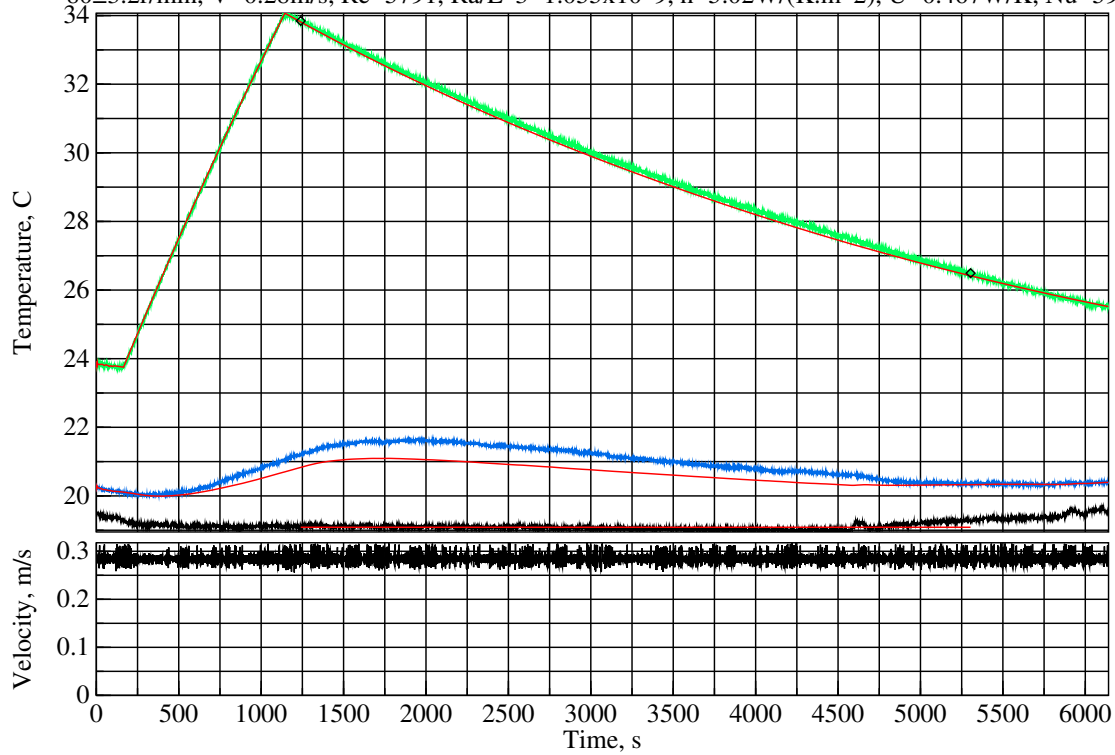
Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
$\Delta T$	11.0K	+21.3%/K	0.10K	2.13%	LM35C differential
$P$	101kPa	+0.0007%/Pa	1.5kPa	1.04%	MPXH6115A6U air pressure
$C_{pt}$	4.69kJ/K	+0.042%/(J/K)	47J/K	1.98%	plate thermal capacity
$C_V$	1.000	-14.2%	0.100	1.42%	vertical reuptake
$L_c$	0.305m	+601%/m	500um	0.30%	characteristic length
$D_{PIR}$	25.4mm	-510%/m	1.0mm	0.51%	insulation thickness
$D_g$	1.00mm	-518%/m	500um	0.26%	air gap
$L_m$	3.57mm	+1103%/m	500um	0.55%	side metal strip width
$k_{PIR}$	22.2 $\frac{mW}{K \cdot m}$	+0.493%/ $\frac{mW}{K \cdot m}$	1.1 $\frac{mW}{K \cdot m}$	0.55%	PIR thermal conductivity
$\epsilon_{XPS}$	0.515	+35.4%	0.010	0.35%	XPS emissivity
$\epsilon_{tp}$	0.890	+42.5%	0.015	0.64%	tape emissivity
$\Omega_{tp}$	0.540	+28.8%	0.020	0.58%	tape coverage
$\epsilon_{rs}$	0.040	+148%	0.010	1.48%	test-surface emissivity
$\epsilon_{wt}$	0.900	+69.6%	0.025	1.74%	wind-tunnel emissivity
				4.33%	combined bias uncertainty



Estimated measurement uncertainties, bi-level 3mm roughness at  $Re = 2901$ .

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
$\Delta T$	10.5K	+20.6%/K	0.10K	2.06%	LM35C differential
$P$	101kPa	+0.0008%/Pa	1.5kPa	1.16%	MPXH6115A6U air pressure
$C_{pt}$	4.69kJ/K	+0.040%/(J/K)	47J/K	1.89%	plate thermal capacity
$\eta$	0.401	+54.5%	0.014	0.76%	anemometer calibration
$C_V$	1.000	-12.7%	0.100	1.27%	vertical reuptake
$L_c$	0.305m	+545%/m	500um	0.27%	characteristic length
$D_{PIR}$	25.4mm	-449%/m	1.0mm	0.45%	insulation thickness
$D_g$	1.00mm	-455%/m	500um	0.23%	air gap
$L_m$	3.57mm	+1024%/m	500um	0.51%	side metal strip width
$k_{PIR}$	22.2 $\frac{mW}{K \cdot m}$	+0.437%/ $\frac{mW}{K \cdot m}$	1.1 $\frac{mW}{K \cdot m}$	0.49%	PIR thermal conductivity
$\epsilon_{XPS}$	0.515	+31.8%	0.010	0.32%	XPS emissivity
$\epsilon_{tp}$	0.890	+38.2%	0.015	0.57%	tape emissivity
$\Omega_{tp}$	0.540	+25.9%	0.020	0.52%	tape coverage
$\epsilon_{rs}$	0.040	+134%	0.010	1.34%	test-surface emissivity
$\epsilon_{wt}$	0.900	+62.6%	0.025	1.57%	wind-tunnel emissivity
				4.15%	combined bias uncertainty
Symbol	Nominal	Sensitivity	Variability	Uncertainty	Component
$\omega$	40.1r/min	+0.545%/(r/min)	2.4r/min	1.28%	fan rotation rate
				4.88%	RSS combined uncertainty

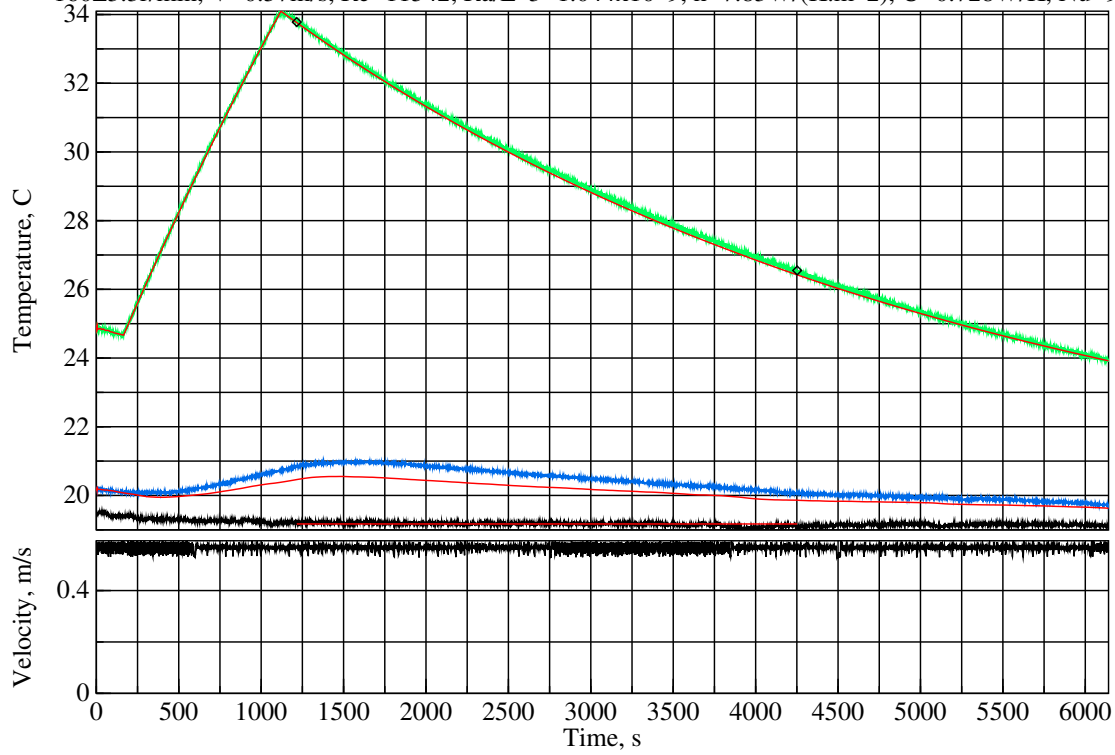
20160604T012434Z – mixed Convection – Roughness=3.00mm; T=19.1+10.7°C; +0.00°  
 80±3.2r/min, V=0.28m/s, Re=5791, Ra/L^3=1.055x10^9, h=5.02W/(K.m^2), U=0.467W/K, Nu=59.9



Estimated measurement uncertainties, bi-level 3mm roughness at  $Re = 5791$ .

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
$\Delta T$	10.7K	+17.9%/K	0.10K	1.79%	LM35C differential
$P$	101kPa	+0.0009%/Pa	1.5kPa	1.30%	MPXH6115A6U air pressure
$C_{pt}$	4.69kJ/K	+0.037%/(J/K)	47J/K	1.72%	plate thermal capacity
$\eta$	0.401	+127%	0.014	1.78%	anemometer calibration
$C_V$	1.000	-10.1%	0.100	1.01%	vertical reuptake
$L_c$	0.305m	+450%/m	500um	0.22%	characteristic length
$\varsigma$	6.00mm	+3539%/m	100um	0.35%	post height
$D_{PIR}$	25.4mm	-417%/m	1.0mm	0.42%	insulation thickness
$D_g$	1.00mm	-422%/m	500um	0.21%	air gap
$L_m$	3.57mm	+851%/m	500um	0.43%	side metal strip width
$k_{PIR}$	22.2 $\frac{mW}{K \cdot m}$	+0.407%/ $\frac{mW}{K \cdot m}$	1.1 $\frac{mW}{K \cdot m}$	0.45%	PIR thermal conductivity
$\epsilon_{XPS}$	0.515	+25.2%	0.010	0.25%	XPS emissivity
$\epsilon_{tp}$	0.890	+30.3%	0.015	0.45%	tape emissivity
$\Omega_{tp}$	0.540	+20.5%	0.020	0.41%	tape coverage
$\epsilon_{rs}$	0.040	+106%	0.010	1.06%	test-surface emissivity
$\epsilon_{wt}$	0.900	+49.3%	0.025	1.23%	wind-tunnel emissivity
				4.00%	combined bias uncertainty
Symbol	Nominal	Sensitivity	Variability	Uncertainty	Component
$\omega$	80.1r/min	+0.635%/(r/min)	3.2r/min	2.01%	fan rotation rate
				5.67%	RSS combined uncertainty

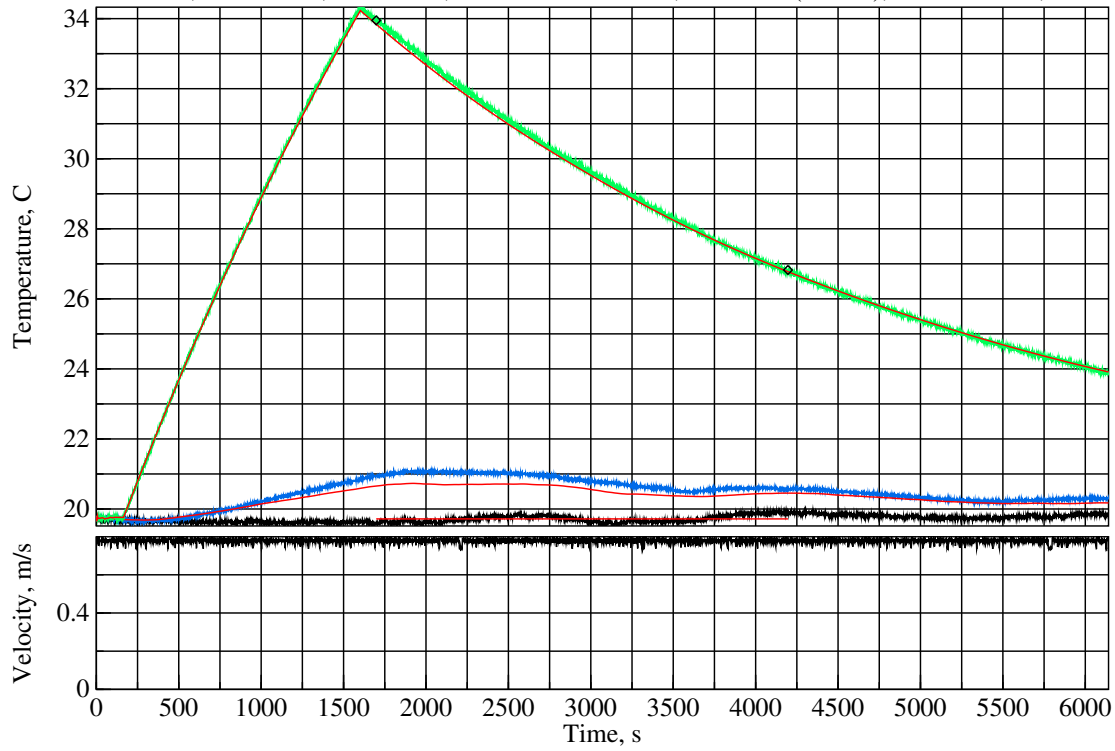
20160604T031539Z – mixed Convection – Roughness=3.00mm; T=19.2+10.6°C; +0.00°  
 160±3.3r/min, V=0.57m/s, Re=11542, Ra/L^3=1.044x10^9, h=7.83W/(K.m^2), U=0.728W/K, Nu=93.4



Estimated measurement uncertainties, bi-level 3mm roughness at  $Re = 11542$ .

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
$\Delta T$	10.6K	+14.7%/K	0.10K	1.47%	LM35C differential
$P$	101kPa	+0.0010%/Pa	1.5kPa	1.46%	MPXH6115A6U air pressure
$C_{pt}$	4.69kJ/K	+0.031%/(J/K)	47J/K	1.46%	plate thermal capacity
$\eta$	0.401	+206%	0.014	2.90%	anemometer calibration
$C_V$	1.000	-6.38%	0.100	0.64%	vertical reuptake
$\varsigma$	6.00mm	+5890%/m	100um	0.59%	post height
$D_{PIR}$	25.4mm	-294%/m	1.0mm	0.29%	insulation thickness
$L_m$	3.57mm	+597%/m	500um	0.30%	side metal strip width
$k_{PIR}$	22.2 $\frac{mW}{K \cdot m}$	+0.289%/ $\frac{mW}{K \cdot m}$	1.1 $\frac{mW}{K \cdot m}$	0.32%	PIR thermal conductivity
$\epsilon_{tp}$	0.890	+19.1%	0.015	0.29%	tape emissivity
$\Omega_{tp}$	0.540	+13.0%	0.020	0.26%	tape coverage
$\epsilon_{rs}$	0.040	+67.0%	0.010	0.67%	test-surface emissivity
$\epsilon_{wt}$	0.900	+31.0%	0.025	0.78%	wind-tunnel emissivity
				4.14%	combined bias uncertainty
Symbol	Nominal	Sensitivity	Variability	Uncertainty	Component
$\omega$	160r/min	+0.518%/(r/min)	3.3r/min	1.69%	fan rotation rate
				5.35%	RSS combined uncertainty

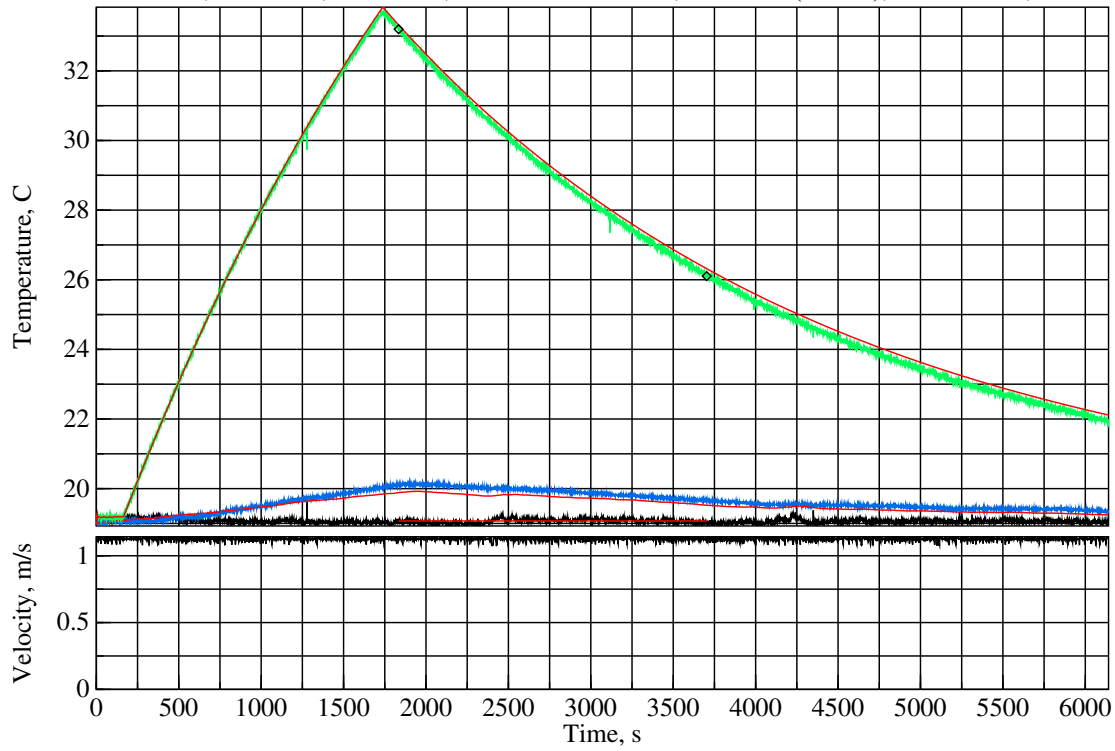
20160604T220844Z – mixed Convection – Roughness=3.00mm; T=19.7+10.2°C; +0.00°  
 220±2.7r/min, V=0.78m/s, Re=15742, Ra/L^3=1.002x10^9, h=10.6W/(K.m^2), U=0.985W/K, Nu=126.2



Estimated measurement uncertainties, bi-level 3mm roughness at  $Re = 15742$ .

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
$\Delta T$	10.2K	+13.8%/K	0.10K	1.38%	LM35C differential
$P$	100kPa	+0.0010%/Pa	1.5kPa	1.50%	MPXH6115A6U air pressure
$C_{pt}$	4.69kJ/K	+0.029%/(J/K)	47J/K	1.35%	plate thermal capacity
$\eta$	0.401	+227%	0.014	3.19%	anemometer calibration
$C_V$	1.000	-4.84%	0.100	0.48%	vertical reuptake
$\varsigma$	6.00mm	+6528%/m	100um	0.65%	post height
$D_{PIR}$	25.4mm	-232%/m	1.0mm	0.23%	insulation thickness
$L_m$	3.57mm	+497%/m	500um	0.25%	side metal strip width
$k_{PIR}$	22.2 $\frac{mW}{K \cdot m}$	+0.230%/ $\frac{mW}{K \cdot m}$	1.1 $\frac{mW}{K \cdot m}$	0.26%	PIR thermal conductivity
$\epsilon_{tp}$	0.890	+14.6%	0.015	0.22%	tape emissivity
$\epsilon_{rs}$	0.040	+51.3%	0.010	0.51%	test-surface emissivity
$\epsilon_{wt}$	0.900	+23.8%	0.025	0.59%	wind-tunnel emissivity
				4.22%	combined bias uncertainty
Symbol	Nominal	Sensitivity	Variability	Uncertainty	Component
$\omega$	220r/min	+0.414%/(r/min)	2.7r/min	1.12%	fan rotation rate
				4.78%	RSS combined uncertainty

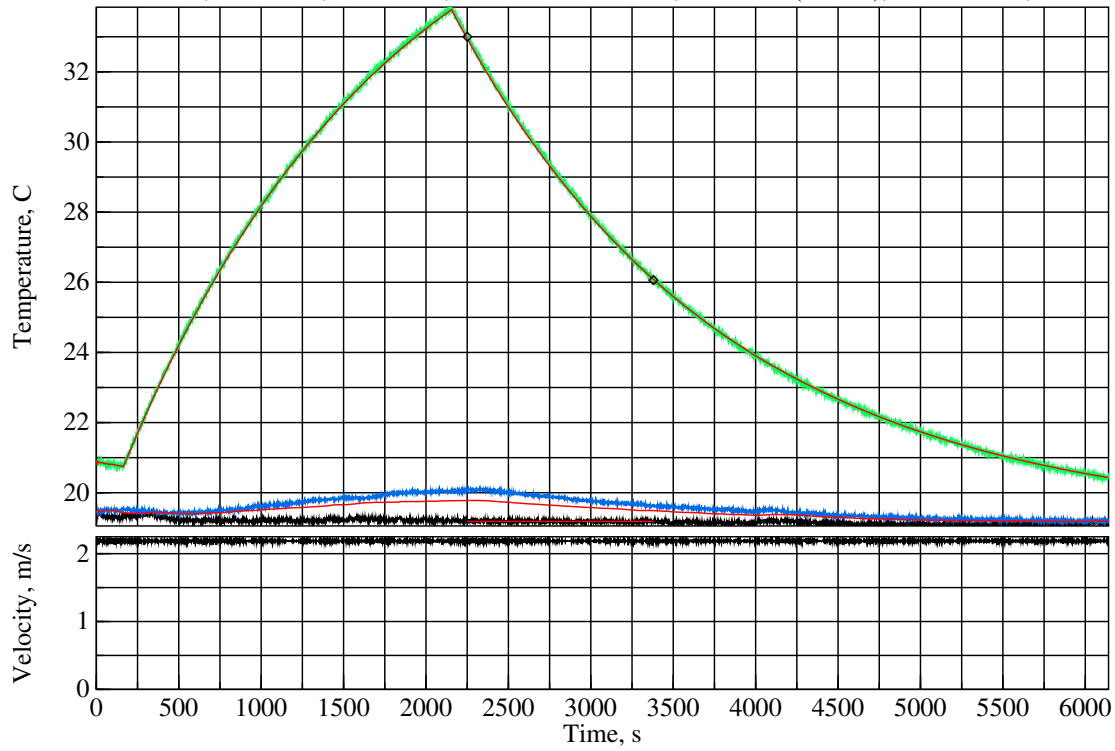
20160604T124012Z – mixed Convection – Roughness=3.00mm; T=19.1+10.2°C; +0.00°  
 320±2.8r/min, V=1.1m/s, Re=22925, Ra/L^3=1.012x10^9, h=15.0W/(K.m^2), U=1.39W/K, Nu=178.9



Estimated measurement uncertainties, bi-level 3mm roughness at  $Re = 22926$ .

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
$\Delta T$	10.2K	+12.7%/K	0.10K	1.27%	LM35C differential
$P$	101kPa	+0.0010%/Pa	1.5kPa	1.50%	MPXH6115A6U air pressure
$C_{pt}$	4.69kJ/K	+0.027%/(J/K)	47J/K	1.25%	plate thermal capacity
$\eta$	0.401	+236%	0.014	3.31%	anemometer calibration
$C_V$	1.000	-3.40%	0.100	0.34%	vertical reuptake
$\zeta$	6.00mm	+6952%/m	100um	0.70%	post height
$L_m$	3.57mm	+407%/m	500um	0.20%	side metal strip width
$\epsilon_{rs}$	0.040	+35.8%	0.010	0.36%	test-surface emissivity
$\epsilon_{wt}$	0.900	+16.6%	0.025	0.41%	wind-tunnel emissivity
				4.18%	combined bias uncertainty
Symbol	Nominal	Sensitivity	Variability	Uncertainty	Component
$\omega$	320r/min	+0.295%/(r/min)	2.8r/min	0.82%	fan rotation rate
				4.49%	RSS combined uncertainty

20160604T170841Z – mixed Convection – Roughness=3.00mm; T=19.2+10.0°C; +0.00°  
 640±4.6r/min, V=2.2m/s, Re=44390, Ra/L^3=0.988x10^9, h=27.2W/(K.m^2), U=2.53W/K, Nu=325.0

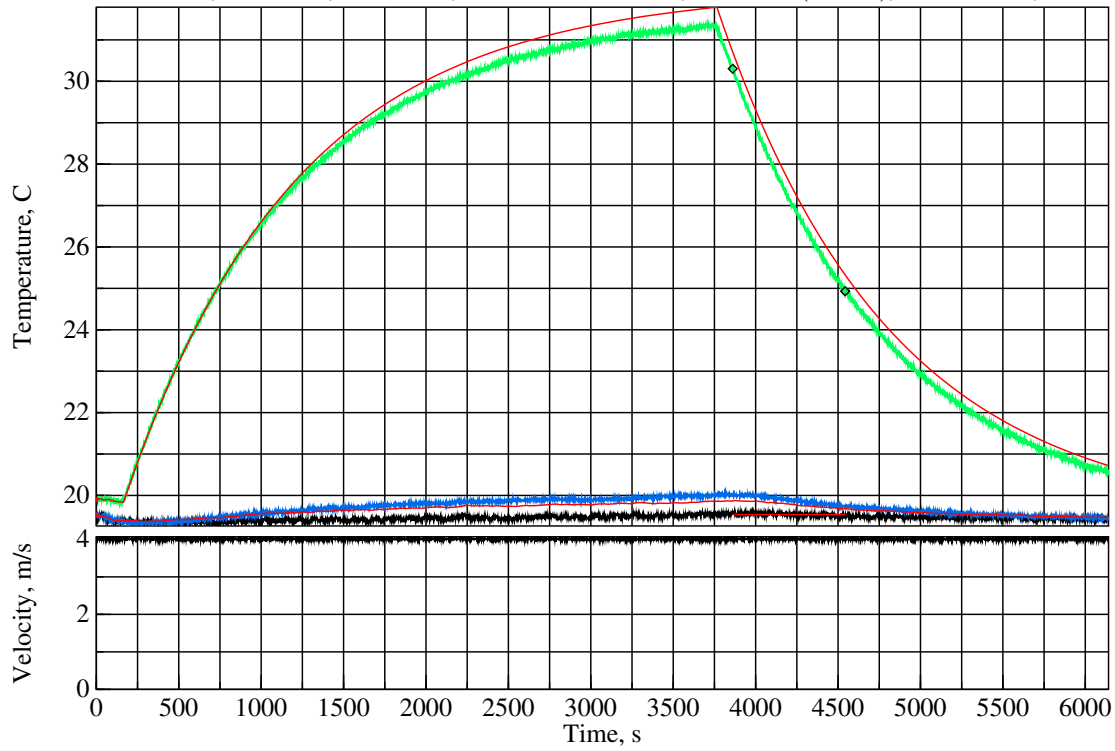


Estimated measurement uncertainties, bi-level 3mm roughness at  $Re = 44388$ .

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
$\Delta T$	9.98K	+11.6%/K	0.10K	1.16%	LM35C differential
$P$	101kPa	+0.0009%/Pa	1.5kPa	1.40%	MPXH6115A6U air pressure
$C_{pt}$	4.69kJ/K	+0.024%/(J/K)	47J/K	1.14%	plate thermal capacity
$\eta$	0.401	+212%	0.014	2.97%	anemometer calibration
$\varsigma$	6.00mm	+9044%/m	100um	0.90%	post height
$\epsilon_{wt}$	0.900	+8.77%	0.025	0.22%	wind-tunnel emissivity
				3.81%	combined bias uncertainty
Symbol	Nominal	Sensitivity	Variability	Uncertainty	Component
$\omega$	640r/min	+0.133%/(r/min)	4.6r/min	0.62%	fan rotation rate
				4.00%	RSS combined uncertainty



20160604T191826Z – mixed Convection – Roughness=3.00mm; T=19.5+07.8°C; +0.00°  
 1280±5.0r/min, V=4.0m/s, Re=81245, Ra/L^3=0.777x10^9, h=47.9W/(K.m^2), U=4.45W/K, Nu=570.5



Estimated measurement uncertainties, bi-level 3mm roughness at  $Re = 81241$ .

Symbol	Nominal	Sensitivity	Bias	Uncertainty	Component
$\Delta T$	7.79K	+14.1%/K	0.10K	1.41%	LM35C differential
$P$	100kPa	+0.0008%/Pa	1.5kPa	1.16%	MPXH6115A6U air pressure
$C_{pt}$	4.69kJ/K	+0.023%/(J/K)	47J/K	1.08%	plate thermal capacity
$\eta$	0.401	+141%	0.014	1.98%	anemometer calibration
$u_u$	7.787	+2.63%	0.100	0.26%	diffuser airflow upper bound
$\varsigma$	6.00mm	+12449%/m	100um	1.24%	post height
				3.19%	combined bias uncertainty
Symbol	Nominal	Sensitivity	Variability	Uncertainty	Component
$\omega$	1.28kr/min	+0.052%/(r/min)	5.0r/min	0.26%	fan rotation rate
				3.24%	RSS combined uncertainty